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15 JUN 1999

The Patent Office

Cardiff Road
Newport
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1. Your reference

AA 1464 GB

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2. Patent application number
(The Patent Office will fill in this part)

9913732.5

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3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

JOHNSON MATTHEY PUBLIC LIMITED COMPANY
2-4 COCKSPUR STREET
TRAFALGAR SQUARE
LONDON SW1Y 5BQ

Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

GB 536263007

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4. Title of the invention

IMPROVEMENTS IN EMISSIONS CONTROL

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5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

IAN CARMICHAEL WISHART
JOHNSON MATTHEY TECHNOLOGY CENTRE
BLOUNTS COURT
SONNING COMMON
READING RG4 9NH

Patents ADP number *(if you know it)*

7253312001

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6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

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Description	5
Claim*(s)*	1
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Signature [signature] Date 14 June 99

I C WISHART

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IMPROVEMENTS IN EMISSIONS CONTROL

The present invention concerns improvements in emissions control. More especially, the invention concerns improvements in the control of particulates and NOx from diesel engines.

The use of emission control catalysts for engine exhaust clean-up is well established. Diesel engines have different characteristics from gasoline-fuelled engines, with a different mix of pollutants caused by the different fuels, the different combustion characteristics in each engine and the lower temperatures met with in exhausts from diesel engines. Additionally, diesel engines emit more noticeable particulates, especially under heavy load and upon start-up, than gasoline engines. In general, it can be said that diesel engines emit less NOx than a gasoline engine under most conditions, but because diesel engines mostly or exclusively operate on a high air to fuel ratio, that is are "lean"-burn engines, the chemistry of the exhaust gas does not favour NOx reduction by aftertreatement, because of the excess of oxidising species. There are engine design options available, which can reduce the quantities of NO_x or of particulates but not both simultaneously.

To meet the various emission regulations already or about to enter force, it has become necessary to treat diesel exhausts in various ways. Oxidation catalysts, which catalyse the oxidation of unburnt hydrocarbons ("HCs") and carbon monoxide ("CO") are now regularly fitted to light duty diesels, and particulate traps of various types are becoming commonplace on heavy duty diesels as used in trucks, buses and some stationary engines. A technique for improving exhaust gas emissions, especially NOx emissions from diesel engines is exhaust gas recirculation ("EGR"), which takes a proportion of the exhaust gas and recirculates it into the engine cylinders. Generally, about 30 up to 75vol% of the exhaust gases are recirculated, depending upon the characteristics of the particular engine and the emission limits which must be met. Although EGR has been used with gasoline engines for many years, principally to improve fuel economy, it has only been more recently fitted to diesel engines; we believe that most diesel vehicles currently fitted with EGR are passenger car light duty diesel engines. In the case of engines fitted with a catalyst, the exhaust gas is always taken from upstream of the catalyst. It is generally expected that EGR would have a significant effect on emissions from heavy duty diesel engines, that is those

fitted to heavy trucks and buses. Because of the engineering problems caused by the very different exhaust characteristics compared to light duty diesel engines, however, this has proved difficult to achieve. In particular, there is currently no commercial source of an EGR valve of suitable size and materials to be fitted to a heavy duty diesel engine.

We refer also to a device marketed as the "CRT™" by Johnson Matthey PLC. This device is described in US Patent No 4,902,487 and is a continuously regenerative particulate trap. Unlike the vast majority of particulate traps, however, this device regenerates continuously or semi-continuously *in situ* without the need for periodic replacement or electrical heating to ignite the soot. Such device relies upon a catalyst system which generates NO_2 which we found is effective to cause low temperature combustion of trapped soot particles.

The principle of the CRT has been adopted by Hino in their published Japanese patent applications JP 8338320 and JP 9088727, in combination with EGR. However, such systems as described are not believed to be capable of use in true heavy duty diesel applications.

We have recently disclosed in WO 99/09307 a novel combination which can offer very low levels of NOx. That invention provides a diesel engine system comprising a diesel engine and an exhaust system therefor, characterised in that the exhaust system incorporates a catalyst effective to convert NO to NO_2 under normal operating conditions, a trap for particulates mounted downstream of the catalyst and an exhaust gas recirculation system mounted downstream of the trap, and provided with cooling means to cool the portion of exhaust gas which is recirculated.

It is noted that the gases for exhaust gas recirculation are taken downstream of the trap, thus benefitting from reduced particulate.

The present invention provides a modified EGR and catalyst system, comprising a diesel engine provided with an exhaust system, which exhaust system comprises an oxidation catalyst and an exhaust gas recirculation system, characterised in that the exhaust gas recirculation system is mounted downstream of the oxidation catalyst, and preferably

upstream of a trap for particulates, such that the portion of exhaust gases recirculated has passed through the oxidation catalyst.

Preferably, the oxidation catalyst is effective to oxidise at least a portion of NO in the exhaust gases to NO_2, under typical conditions for said engine. More preferably, the catalyst is a high loading platinum catalyst carried on a metal or ceramic flow-through honeycomb catalyst support. Such a support may have from 50 to 800 cells/sq.in, preferably about 400cpsi. The catalyst may have a loading from 10 to 150 gm Pt/cu ft of catalyst, preferably 75 to 100g/cu ft, optionally in association with one or more other platinum group metals and/or one or more base metal catalysts or promoters, such as Ce, V, W or Zr.

The present invention also provides a process for the reduction of NOx and particulates in diesel engine exhaust gases, comprising, in order, converting at least a portion of the NO in the exhaust gases to NO_2 by passing the gases over a catalyst, recirculating a portion of the gases leaving the catalyst to the engine cylinders, and trapping at least the majority of carbonaceous particles in the remaining gases on a trap and continuously or semi-continuously oxidising said particles.

The exhaust gas recirculation may be carried out using essentially well established technology, using valves in the exhaust system and a control system. It is believed that the present invention may be operated most effectively at a lower recirculation ratio (*eg* 5 to 30% by vol preferably 12 to 20% by vol) than is normal. Although engine intake vacuum may provide adequate EGR, it may be preferable to provide pumping to provide a vacuum using a variable speed fan or pump operating under the control of the engine management unit.

Preferably, the EGR valve is mounted downstream, in the recirculation loop, of the cooler, whereby a proportion of the particulate is removed from the gases in the cooler. Since the recirculated gases are enriched with NO_2, it is possible, depending upon gas temperatures, flow rates and resistence times, for a proportion of particulates to be wholly or partially combusted within the cooler or during flight.

It is to be realised that since only a portion of the exhaust gases is recycled, the system and process of the invention desirably include a particulate trap downstream of the EGR loop, such that all the gases fed to the exhaust outlet pipe are filtered. A preferred trap is an extruded ceramic, *e.g.* cordierite, wall flow filter. Other filters including metal mesh or metal or ceramic foams, may also be considered.

The present invention is believed to offer, in its preferred embodiments, certain unexpected advantages. The invention, because it does not depend upon a reduction catalyst reaching light-off temperature, is effective to reduce NOx at all engine operating temperatures. Additionally, traditional EGR systems suffer from wear and other degradation both of the EGR valves which are used to extract the recirculating portion of the exhaust gases, and on engine or exhaust components themselves. Such degradation may lead to expensive rebuilds and engine downtime, and a system that offers the potential for savings in this area has considerable economic value.

The portion of recirculated exhaust gases is desirably cooled before being admixed with combustion air for the engine. The combustion air is desirably at super-atmospheric pressure resulting from turbo-charger or supercharger, and it is well known to cool such combustion air to increase its density before intake into the cylinders.

Cooling may be achieved separately or when the recirculated gases and fresh combustion air are combined. Desirably a forced air cooler is used, although a liquid (e.g. water-) cooler may be used.

In accordance with the principles of the present invention, the skilled person may adapt the invention to different diesel engines and in different ways achieve the benefits of the invention.

The present invention is illustrated with reference to the accompanying schematic drawing of one embodiment of the invention.

A heavy duty diesel engine is generally indicated by 1. The engine exhaust manifold, 2, connects to a turbine, 3, and feeds into an exhaust system, 4. A catalyst element, 5a, and

a filter element, 5b, are mounted in a housing, 5. There is a pipe, 6, connected between the catalyst and filter elements, which can extract a portion of exhaust gas, according to the status of the exhaust flow valve described below. The portion of exhaust gas is passed to an exhaust gas cooler, generally indicated by 7, which is effective to reduce the temperature of the exhaust gas to the range 80 to 150°C. The exhaust gas cooler may be a liquid-cooled device, as shown in the drawing, or air cooled. The cooled gas then passes through an exhaust gas flow valve, 8, which is actuated under the control of an engine management unit (not shown). According to the position of the valve, exhaust gas is extracted through pipe 6 for recirculation. The engine management unit utilises conventional sensing to determine suitable load conditions for EGR operation, for example at idle and up to about half load conditions, including acceleration, but the use of EGR under full load conditions is not presently expected to be advantageous.

The exhaust gas is then blended with fresh air for combustion taken through an air intake, 9. Desirably an inter-cooler unit, 10, cools the combustion air and recycled exhaust gas to about 25 to 40°C before it is compressed by a turbocharger unit, 11, driven by a shaft from the turbine, 3. The charge of gas is then passed through the standard inter-cooler unit, 12, to cool the gas to about 35 to 60°C before it is fed to the engine.

CLAIMS

1. A diesel engine provided with an exhaust system comprising an oxidation catalyst and an exhaust gas recirculation system ("EGR"), characterised in that the EGR system is mounted downstream of the oxidation catalyst, so that the portion of exhaust gases recirculated has passed through the oxidation catalyst.

2. A diesel engine system according to claim 1, wherein a trap for particulates is mounted downstream of the EGR system.

3. A system according to claim 2, so arranged that all of the remainder of the exhaust gases not recirculated, passes through the particulate trap.

4. A system according to claim 2, wherein a trap for particulates is mounted in the EGR system.

5. A system according to claim 2, 3 or 4, wherein the particulate trap is effective to trap at least 50% by wt of particulates inthe exhaust gases.

6. A system according to claim5, wherein the particulate trap comprises by-pass means such that blocking of the filter does not cause excessive back-pressure in the exhaust system.

7. A system according to any one of the preceding claims, wherein the recirculation ratio of the EGR system may be varied from 5 to 30% by volume.

8. A system according to any one of the preceding claims, comprising a cooler for the recirculated gases, said cooler being mounted upstream of the EGR valve.

9. A system according to claim1, substantially as hereinbefore described.

IMPROVEMENTS IN EMISSIONS CONTROL

Abstract

A diesel engine, 1, has an exhaust system, 4, and an oxidation catalyst, 5a. Exhaust gas for recirculation is taken through pipe, 6, downstream of the catalyst, and preferably upstream of a filter, 5b, for soot. The recirculated gases are passed through a cooler, 7, upstream of the EGR valve 8. Good removal of soot and NO_x is achieved even at low exhaust gas temperature.

(Sole Figure to be used)

1